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“ Operational Impact Analysis: Vital Pulp Therapy versus Non-Surgical Root Canal Therapy in the Cariously Pulp Exposed Permanent Molar ”

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Operational Impact Analysis: Vital Pulp Therapy versus Non-Surgical Root Canal Therapy in the Cariously Pulp Exposed Permanent Molar

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Key words: Vital pulp therapy, endodontics, root canal therapy, military readiness, operational impact analysis.

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ABSTRACT

Introduction: In the military, operational readiness is the top priority. By preventing and treating dental disease, the military provider minimizes emergency and routine visits while maximizing the operational capabilities of forward deployed military assets. This operational impact analysis compared full coronal pulpotomy (FCP) against root canal therapy (RCT) in the cariously pulp exposed permanent molar to identify which of these two treatment modalities following a carious pulp exposure in a permanent molar is more operationally suitable in the US Armed Forces. **Methods:** A Markov model was constructed for a simulated adult patient with a permanent, mature, cariously pulp exposed molar tooth. Transition probabilities were obtained from previously published literature. A Monte Carlo simulation served to mathematically evaluate and predict the effects and operational impact of FCP vs RCT modalities for carious pulp exposures in mature permanent molars in a combatant population matrix (Brigade Combat Team). **Results:** Microsimulation analysis showed that when FCP was performed on all cariously pulp exposed permanent molars, there was a five-fold decrease in cumulative time Service members within the Brigade Combat Team spent in Class 3 dental readiness status. Additionally, early FCP failures were estimated to account for 13 additional subsequent emergency dental visits. **Conclusions:** FCP has the potential to improve the readiness of a Brigade Combat Team with a potential increase to the amount of subsequent emergency visits.

INTRODUCTION

In the military, we have a unique challenge to manage with our patients. We not only need to ensure their wellness is maintained, but also and importantly, we need to ensure the force readiness is adequate so our combatant units can perform their duties of preserving our freedom and democracy. In order to achieve this, the military clinician's triaging of patients is different than that of a community clinician. We, as military providers, need to ensure we act as force multipliers, meaning we need to ensure our definitive treatments have a quick turn-around time so that the combatants can return to their units fast to augment the front lines. Additionally, we need to ensure our definitive treatments have good long-term prognoses so that we do not trigger a higher incidence of emergency appointments in combat zones. According to Liewehr¹, a review of the literature indicated 20-25% of all Soldiers will report to dental sick call during a 1-year deployment, and approximately half of them will require some sort of endodontic intervention. Consequently, in the military, we measure readiness via a dental readiness classification (DRC)² system in which a patient is assigned 1 of 3 classifications following a dental examination. DRC1 describes a worldwide deployable patient with a current dental examination and one who requires no dental treatment or re-evaluation. DRC2 describes a worldwide deployable patient with a current dental examination and requires only non-urgent dental treatment or re-evaluation. DRC3 describes a patient with urgent dental treatment needs that are likely to result in a dental emergency within a 12-month period if not addressed. This is often the case in a patient with large carious lesions encroaching upon the dental pulp.

When teeth are treated for large carious lesions encroaching upon the dental pulp, a carious exposure of the pulp may occur. Therefore, to preserve the tooth in the mouth, we are often faced with two treatment options: vital pulp therapy or root canal therapy. Vital pulp therapy (VPT) refers to treatment of the tooth pulp that will preserve its vitality and can be performed via pulp capping, partial pulpotomy, and full coronal pulpotomy. While all three of these strategies are different, each aims at maintaining healthy and vital pulp tissue within the root canal system of the tooth. This research only analyzed the effects of FCP. The European Society of Endodontology³ defines FCP as follows:

- Full pulpotomy: Complete removal of the coronal pulp and application of a biomaterial directly onto the pulp tissue at the level of the root canal orifice(s), prior to placement of a permanent restoration.

With the advent of newer materials such as bioceramics and calcium silicates, full coronal pulpotomy is proving to be effective in the management of carious pulpal exposures of permanent teeth. We know from current evidence that specific factors affecting the outcomes from this type of vital pulp therapy are inconclusive at this time, however, we also know from Aguilar and Linsuwanont's⁴ 2011 systematic review that FCP has a 94-99% success rates in periods of >6months to >3years. A randomized clinical trial by Taha et al⁵ in 2017 found that VPT performed with MTA had an 83% success rate in the first year and an 85% success in the

second year after partial pulpotomy following a cariously exposed pulp on patients 20 years and older. The authors found that the success rates of CaOH were not as high, with 55% success on the first year and 43% on the second year. Another bioactive material present in the literature is Biodentine. In 2019, a prospective study by Awawdeh et al⁶ aimed to evaluate the performance of MTA and Biodentine in pulp capping cariously exposed, mature, permanent teeth. The authors did not find a significant difference in the overall success rate between the two materials, with up to 100% success rate for each at two years. At the 3-year follow-up, the success rate decreased to 93.8% (MTA = 96% and Biodentine = 91.7%). Despite these promising findings, a paradigm shift has yet to be realized with RCT still being the primary treatment for many clinicians faced with permanent teeth with carious pulp exposures.

On the other hand, root canal therapy (RCT) is the procedure in which the pulp of the involved tooth is extirpated, and the canals are disinfected and filled with an inert material (gutta percha). When compared against VPT, more cervical and radicular dentin is removed during RCT, and this loss of tooth structure can significantly shorten the life span of the tooth. Despite this, RCT has shown a predictably high degree of success. In a retrospective study by Salehrabi et al⁷, the outcomes of 1,462,936 teeth with initial root canal therapy were analyzed. The study found 97% of teeth were retained in the mouth 8 years after initial treatment. However, some studies have found lower numbers for success rates. Ng et al⁸ conducted a systematic review on tooth survival following RCT. The authors found that the survival of root canal treated teeth ranged from 86% to 93% between 2 and 10 years, with 86% success in 2 -3 years, 93% success in 4 – 5 years and 87% success in 8 – 10 years. However, RCTs can also be unsuccessful and in these cases the only treatment options available are endodontic retreatment, endodontic microsurgery or extraction, the latter being the most likely and realistic in a combat theater environment.

Therefore, since the cost of dental sick call in the military could possibly cost an infantry division around 18,000 man-days of combat effectiveness in a combat theater¹, translating to approximately \$1.8M in monthly costs⁹, the purposes of this research were to identify which treatment modality (FCP or RCT) following a carious pulp exposure in a permanent molar is more operationally suitable in the US Armed Forces, to identify which of these two treatment modalities result in additional emergency visits and how do these treatment options impact military operations.

SIGNIFICANCE

There was a five-fold decrease in cumulative time service members within the Brigade Combat Team spent in Class 3 dental readiness status when FCP was compared to RCT. Early FCP failures were estimated to account for 13 additional subsequent emergency dental visits.

METHODS

A decision analytic modeling by means of a Markov model was constructed using TreeAge Pro (TreeAge Software, Williamstown, MA) to mathematically evaluate and predict the effects and operational impact of FCP vs RCT modalities in a combatant population matrix (Brigade Combat Team). The model followed a mature permanent molar after a carious pulp exposure through either FCP or RCT treatment modalities.

The Model

A Markov model was constructed to simulate the scenarios as shown on Figure 1. After a carious pulp exposure, the tooth will be faced with two different treatment options: FCP or RCT. Transition probabilities were calculated for the outcome of each transition, and whether or not the tooth needs additional treatment (extraction, root canal, endodontic microsurgery). The transition probabilities were estimated by performing a review of the literature, assessing the outcome of every treatment step and the survival or failure rates of all treatments.

Probability Estimates

Data for the Markov model was provided from a review of the literature to obtain success rates and follow-up times for the treatments of interest (FCP and RCT) on cariously pulp exposed, mature, permanent molar teeth. Two electronic databases (PubMed and GreyLit) were screened using filters and Boolean search terms (Supplemental Figures 1 & 2). Supplemental Tables 1 & 2 show included and excluded articles along with the specific reasons for exclusion.

$$\text{Transition Probability} = 1 - (1-p)^{(1/n)}$$

p = failure rate in study

n = number of cycles in study

Combatant Population Matrix

The combatant population matrix of a Brigade Combat Team was constructed based on data extracted from the Corporate Dental System (CDS) as shown on Figure 2. The brigade combat team population matrix in this decision model includes 4314 Soldiers undergoing 6105 operative procedures. We then used data from Whitworth & colleagues¹⁰ where they evaluated the endodontic complications after plastic restorations in general practice to estimate the number of frank carious pulp exposures, which in this case is 122 or 2% of those operative procedures (6,105) within the brigade combat team. After the transition probabilities for each health state were estimated, microsimulations were conducted for a cohort of patients with carious pulp exposures to determine how FCP would affect the average time a patient spent in a dental readiness classification 3 status, the average dental visits and the incidence of dental emergency visits.

Assumptions

Table 1 below shows the assumptions made for this research study.

Early (≤ 6 -months) FCP failures present without lesions but with pain (EMERGENCY VISIT = 1)
Later (> 6 -months) FCP failures present with lesions
Morphology altered equals iatrogenic ledging

Table 1: Assumptions

RESULTS

As shown in Figure 3, the Monte Carlo microsimulation revealed Soldiers undergoing FCP spent an average of 3 days in a DRC3 status, whereas Soldiers undergoing RCT spent an average of 17 days in DRC3 status. Additionally, early failures were estimated to account for an additional 13 subsequent emergency dental visits when patients received FCP therapy.

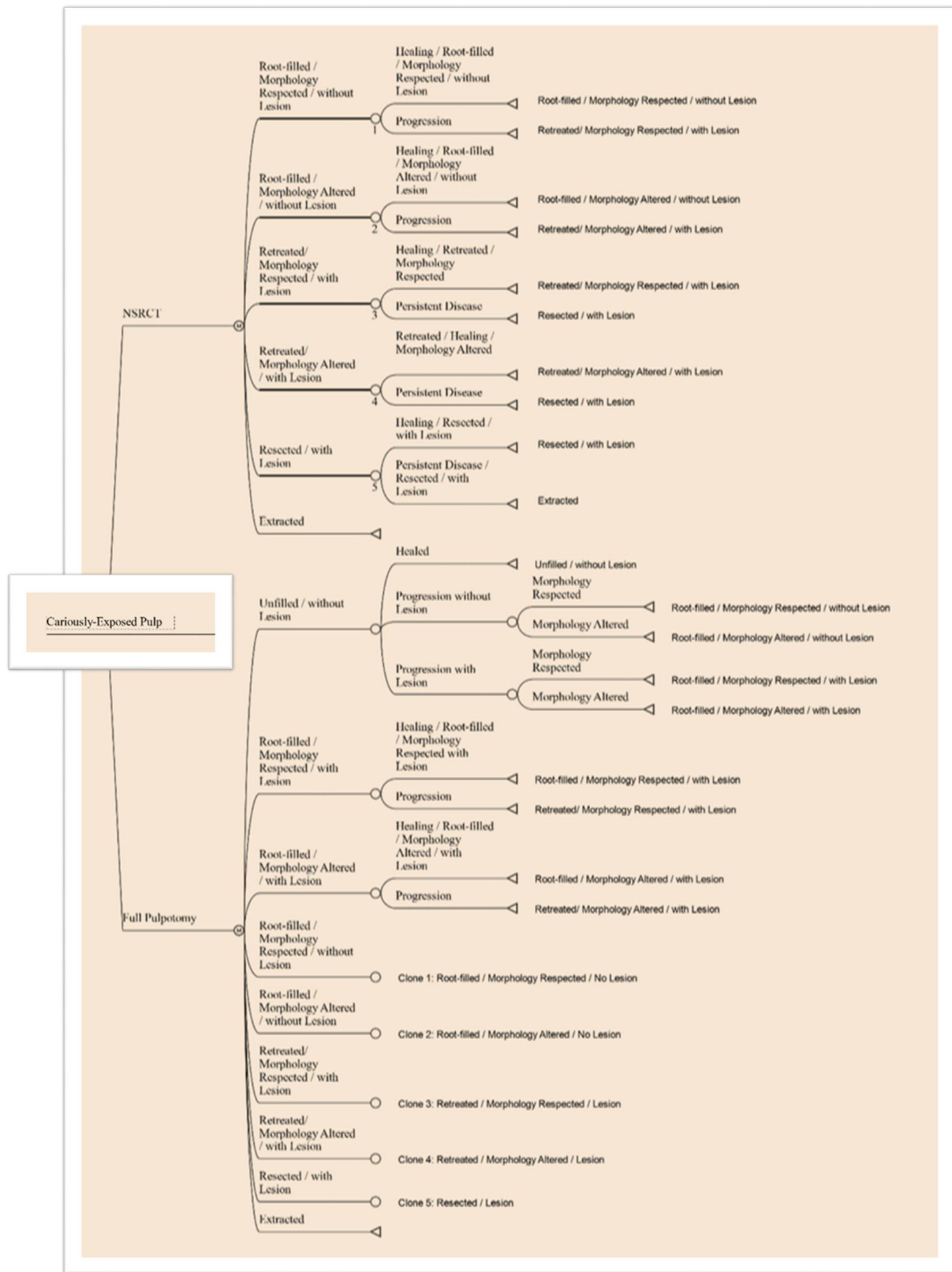


Fig. 1: Decision Tree

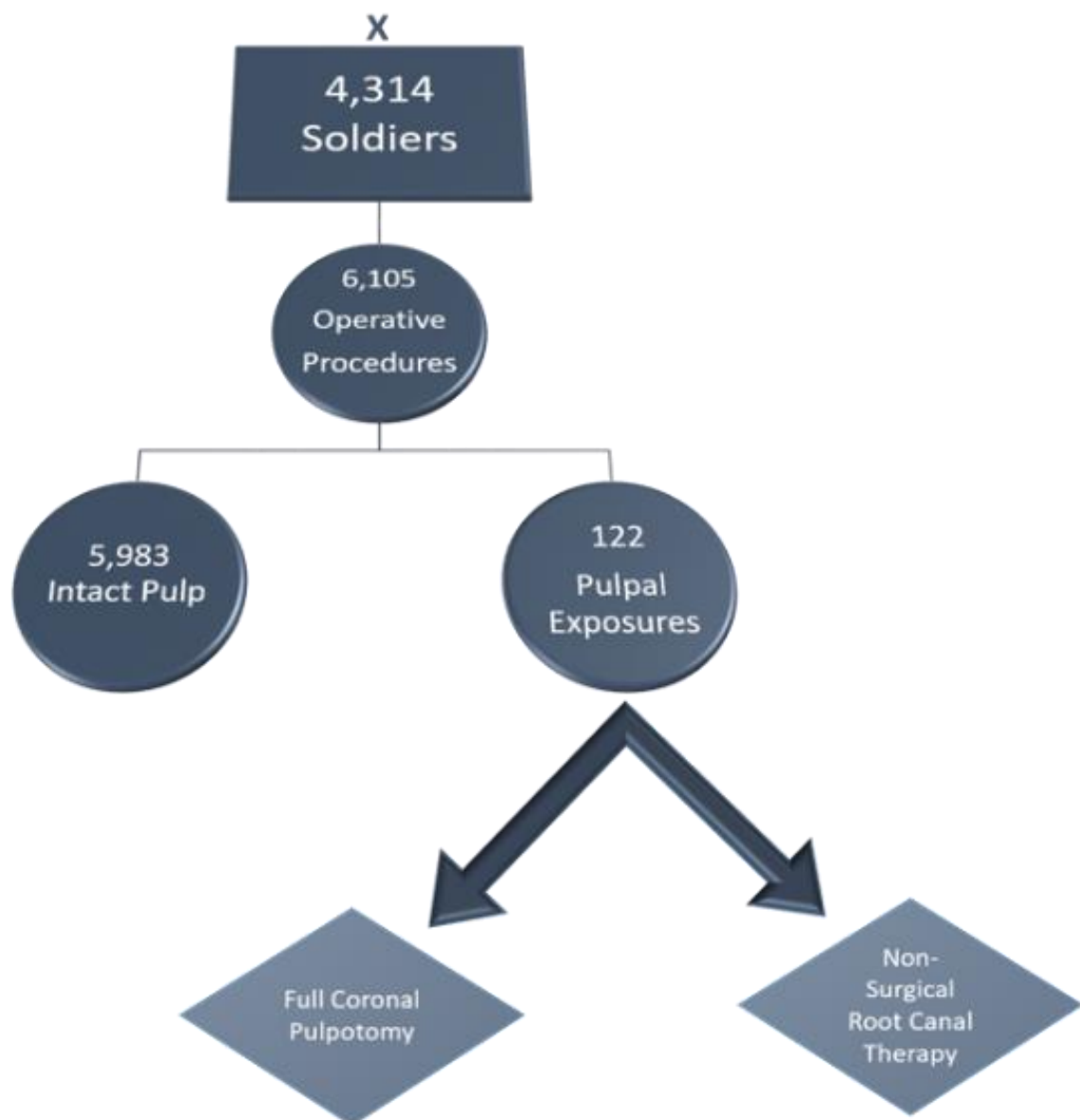


Fig. 2: Brigade Combat Team

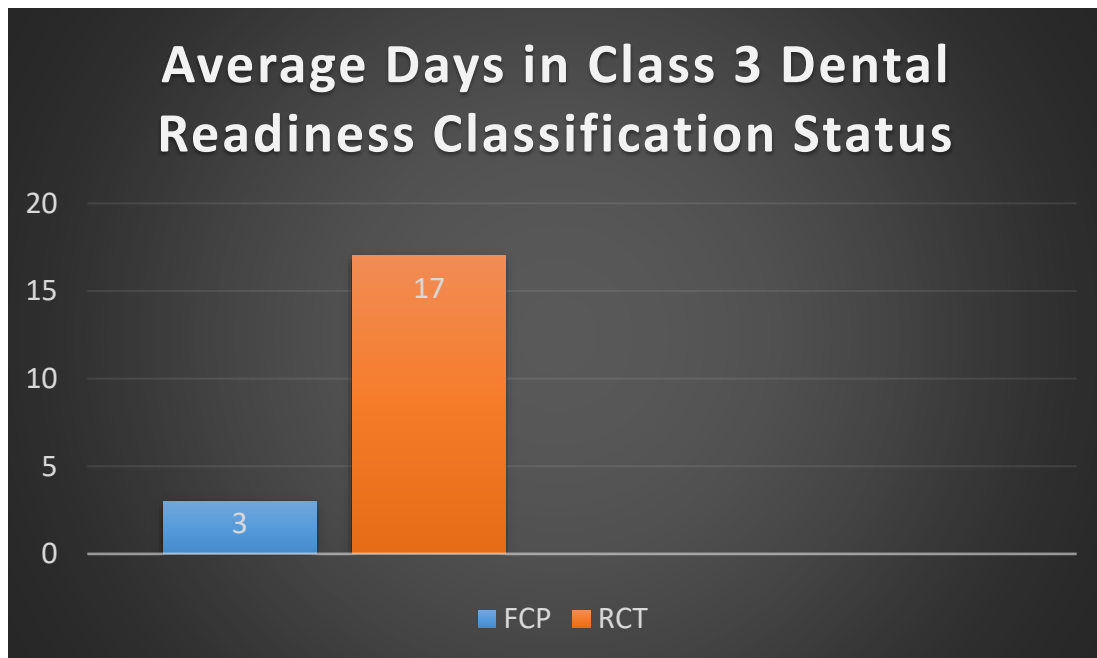


Fig. 3: Average time Soldiers undergoing FCP and RCT spent on DRC3

DISCUSSION

For scenarios such as the ones proposed in this research project, a Markov model is useful to identify disease progression as a series of transitions between health states. Because in the military it is difficult to follow patients due to deployments, field training exercises and personnel re-locations, a Markov model in these situations is beneficial as it gives us the ability to project future health states of a population without actually observing that group of patients over an anticipated period of time¹¹. In our case, the simulations were conducted for a 36-months period since Soldiers within this time frame are more likely to be preparing for and completing a deployment to remote locations without access to advanced dental care. Consequently, 36-months is the pertinent time frame to observe and assess readiness statistics of patients assigned to a brigade combat team undergoing FCP or RCT procedures.

In order to circumvent a typical limitation of the Markov model which is the Markovian assumption or lack of memory between transitions from one state to another, meaning that the probability of a transition to another state is independent of the disease history of the patient¹¹, we elected to add additional health states into our model which took into account previous disease history. In addition to this, we also employed a Monte Carlo microsimulation in order to allow the inclusion of memory into the model. This way our model is not evaluated by matrix multiplication but rather by the Monte Carlo microsimulation which gives us the freedom to define our patient population number (n= 1,000).

The present study found that FCP has the potential to improve readiness of a combatant unit

with minimal impact as to the number of emergency visits. The challenge in the military setting will be establishing and ensuring a treatment standard for FCP with respect to identifying qualified patients, performing the treatment adequately and following the patients for at least 3-6 months after the procedure is completed. Therefore, prior to including FCP as a permanent endodontic treatment option to be performed by military general practitioners, a training and credentialing standard should first be developed.

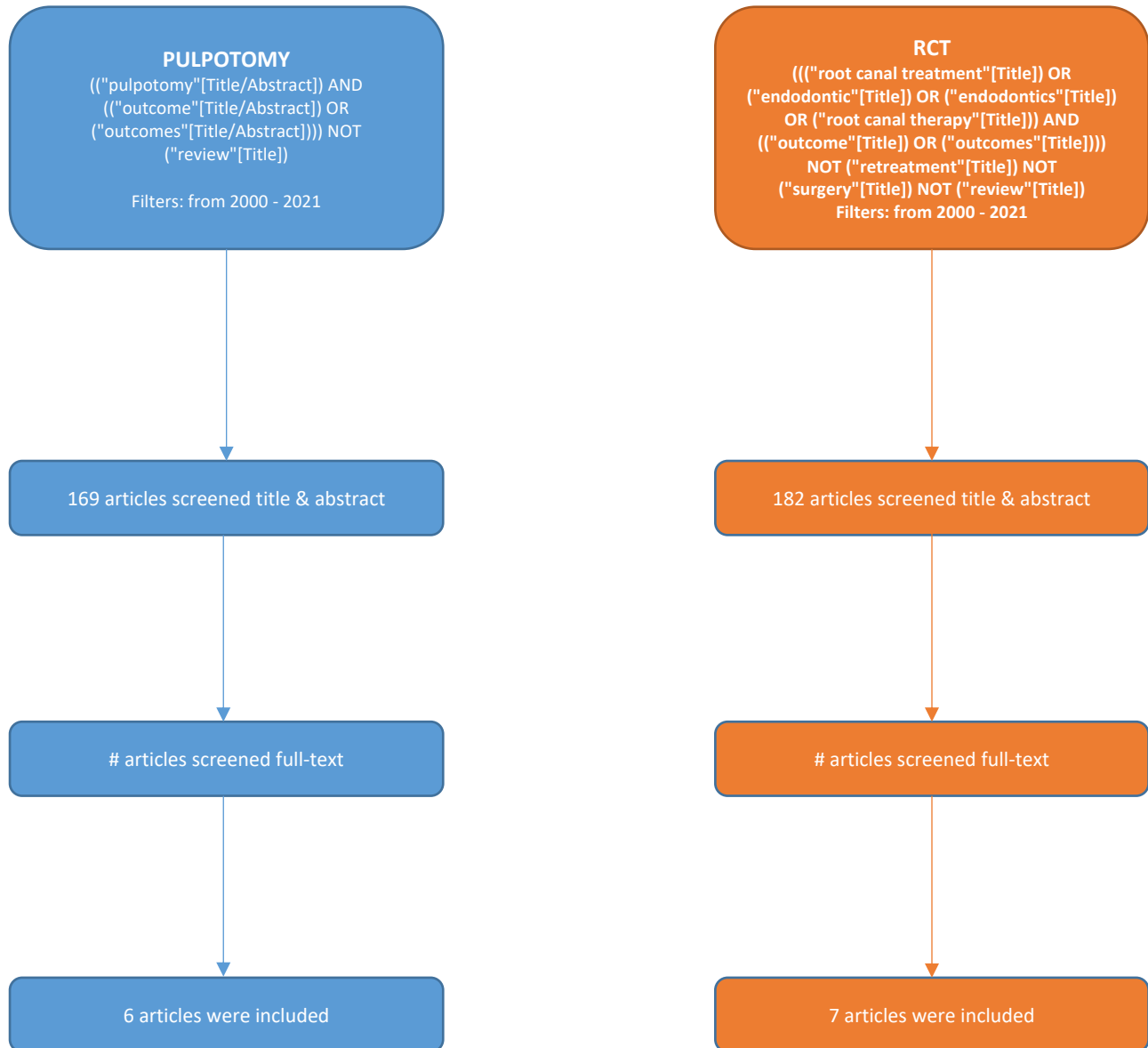
CONCLUSION

This microsimulation model comparison between FCP and RCT indicated a five-fold decrease in cumulative time servicemembers within a BCT spent in DRC 3 status when undergoing FCP, therefore FCP has the potential to improve readiness in a BCT with minimal impact to the amount of subsequent emergency visits when all carious pulp exposures are treated with via this treatment modality. Given the limitations of this research such as relying on patient simulation where factors such as skill variabilities among providers cannot be accounted for as well as suboptimal data collection databases for this type of research (CDS does not allow for extraction of exact numbers of carious pulp exposures), further patient based research should be performed to have a more robust and accurate representation of the impact on readiness and emergency visits when FCP is compared to RCT in the cariously pulp exposed permanent molar in U.S. military personnel.

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Supplemental

SUPPLEMENTAL FIGURE 1. Boolean search for the two primary treatments of interest: RCT & FCP.



SUPPLEMENTAL FIGURE 2. Inclusion and exclusion criteria for literature review.

Inclusion Criteria	Exclusion Criteria
• Year of publication 2000 or newer • Humans only • Adult patients included • Use of bioceramic material • Reported success rate • Reported follow-up time • Use of rubber dam and sodium hypochlorite	• Unrelated studies • Systematic reviews • Inclusion of patients with systemic diseases • Necrotic teeth or teeth with apical radiolucencies

SUPPLEMENTAL TABLE 1. Included Studies

Author	Population	12 months F/U (%)	Up to 24 months F/U (%)	Up to 36 months F/U (%)	Up to 48 months F/U (%)	AMR (%)
Root Canal Therapy (Vital)						
Chugal	104				89.70	2.56
Imura	956		94.90			2.55
Root Canal (Necrotic)						
Chugal	123				98.7	0.325
Penesis	33	85				15
Penesis	30	80				20
Saini	129	75				25
Verma	86	100				0
Full Pulpotomy						
Awawdeh	37	97.3				2.7
Awawdeh	35		100			0
Awawdeh	34			94.1		1.97
Taha (S)	59	98.4				1.6
Taha (S)	40	100				100
Taha (S)	41			92.7		2.43

Include studies up to 48 months of follow-up. Several studies were used more than once if they included more than once follow-up time. AMR was calculated as a linear loss according to follow-up time.

*(S) = studies including symptomatic patients